called a photoplethysmograph (PPG). Time-dependent features of the PPG indicate both pulse rate and a volumetric absorbance change in an underlying artery caused by the propagating pressure pulse.

[0005] Typical PTT measurements determine the time separating a maximum point on the QRS complex (indicating the peak of ventricular depolarization) and a foot of the PPG waveform (indicating the beginning the pressure pulse). PTT depends primarily on arterial compliance, the propagation distance of the pressure pulse (which is closely approximated by the patient's arm length), and blood pressure. To account for patient-dependent properties, such as arterial compliance, PTT-based measurements of blood pressure are typically 'calibrated' using a conventional blood pressure cuff and oscillometry. Typically during the calibration process the blood pressure cuff is applied to the patient, used to make one or more blood pressure measurements, and then left for future measurements. Going forward, the calibration measurements are used, along with a change in PTT, to continuously measure the patient's blood pressure (defined herein as 'cNIBP'). PTT typically relates inversely to blood pressure, i.e., a decrease in PTT indicates an increase in blood pressure.

[0006] A number of issued U.S. Patents describe the relationship between PTT and blood pressure. For example, U.S. Patents 5,316,008; 5,857,975; 5,865,755; and 5,649,543 each describe an apparatus that includes conventional sensors that measure an ECG and PPG, which are then processed to determine PTT. U.S. Patent 5,964,701 describes a finger-ring sensor that includes an optical system for detecting a PPG, and an accelerometer for detecting motion.

SUMMARY OF THE INVENTION

[0007] To improve the safety of hospitalized patients, particularly those in lower-acuity areas, it is desirable to have a body-worn monitor that continuously measures a

plurality of vital signs from a patient, and wirelessly transmits these directly to a nurse or to a central nursing station. Preferably the monitor operates algorithms featuring: 1) a low percentage of false positive alarms/alerts; and 2) a high percentage of true positive alarms/alerts. The term 'alarm/alert', as used herein, refers to an audio and/or visual alarm generated directly by a monitor worn on the patient's body, or alternatively a remote monitor (e.g., a central nursing station). To accomplish this, the invention provides a body-worn monitor that measures a patient's vital signs (e.g. blood pressure, SpO2, heart rate, respiratory rate, and temperature) while simultaneously characterizing their activity state (e.g. resting, walking, convulsing, falling) and posture (upright, supine). The body-worn monitor processes this information to minimize corruption of the vital signs and associated alarms/alerts by motion-related artifacts.

[0008] The body-worn monitor can include a software framework that generates alarms/alerts based on threshold values that are either preset or determined in real time. The framework additionally includes a series of 'heuristic' rules that take the patient's activity state and motion into account, and process the vital signs accordingly. These rules, for example, indicate that a walking patient is likely breathing and has a regular heart rate, even if their motion-corrupted vital signs suggest otherwise.

[0009] The body-worn monitor features a series of sensors that attach to the patient to measure time-dependent PPG, ECG, accelerometer-based motion (ACC), oscillometric (OSC), respiratory rate (RR), and impedance pneumography (IP) waveforms. A microprocessor (CPU) within the monitor continuously processes these waveforms to determine the patient's vital signs, degree of motion, posture and activity level. Sensors that measure these signals typically send digitized information to a wrist-worn transceiver through a serial interface, or bus, operating on a controlled area network (CAN) protocol. The CAN bus is typically used in the automotive industry, which allows different

electronic systems to effectively and robustly communicate with each other with a small number of dropped packets, even in the presence of electrically noisy environments. This is particularly advantageous for ambulatory patients that may generate signals with large amounts of motion-induced noise.

[0010] Blood pressure, a vital sign that is particularly useful for characterizing a patient's condition, is typically calculated from a PTT value determined from the PPG and ECG waveforms. Once determined, blood pressure and other vital signs can be further processed, typically with a server within a hospital, to alert a medical professional if the patient begins to decompensate.

[0011] In other embodiments, PTT can be calculated from time-dependent waveforms other than the ECG and PPG, and then processed to determine blood pressure. In general, PTT can be calculated by measuring a temporal separation between features in two or more time-dependent waveforms measured from the human body. For example, PTT can be calculated from two separate PPGs measured by different optical sensors disposed on the patient's fingers, wrist, arm, chest, or virtually any other location where an optical signal can be measured using a transmission or reflection-mode optical configuration. In other embodiments, PTT can be calculated using at least one time-dependent waveform measured with an acoustic sensor, typically disposed on the patient's chest. Or it can be calculated using at least one time-dependent waveform measured using a pressure sensor, typically disposed on the patient's bicep, wrist, or finger. The pressure sensor can include, for example, a pressure transducer, piezoelectric sensor, actuator, polymer material, or inflatable cuff.

[0012] In one aspect, the invention provides a body-worn monitor featuring a processing system that receives a digital data stream from an ECG system. A cable houses the ECG system at one terminal end, and plugs into the processing system, which

waveform and a digitized version of the analog waveform; (f) determining a calibration from the first digital waveform, the second digital waveform, and a digitized version of the analog waveform; and (g) determining a blood pressure value from the calibration and a pulse transit time.

[0019] Typically the optical signal is generated with an optical sensor configured to be worn around the patient's thumb. PTT is typically calculated from a time difference separating a QRS complex in the ECG waveform and a foot of a PPG waveform. In other embodiments the same optical sensor used to measure the optical waveform features a first LED operating in the red spectral range, and a second LED operating in the infrared spectral range. Optical waveforms measured with these LEDs can additionally be processed to determine SpO2, as is described in detail below.

[0020] The pressure signal is typically generated with a cuff-based pneumatic system wrapped around the patient's arm, and is typically measured during an inflation-based oscillometry measurement. Here, the processing component in the wrist-worn transceiver is further configured to calculate a calibration from a group of pulse transit times, wherein each pulse transit time in the group is measured when a different pressure is applied to the patient's arm. These data are then processed with a model that estimates an 'effective' blood pressure in the patient's arm during the inflation-based measurement, and uses this to estimate a relationship between PTT and blood pressure for the patient. This relationship represents a calibration that is then used with follow-on PTT measurements to measure the patient's cNIBP.

[0021] In another aspect, the invention provides a body-worn vital sign monitor featuring a processing component that includes a system for detecting an identifying code from a medical professional, and in response rendering a specific graphical user interface (GUI) on the wrist-worn transceiver. Preferably the system for detecting an identifying

code is a barcode scanner, and the identifying code is a barcode printed on, e.g., the badge of the medical professional. Alternatively, a system based on radio-frequency identifying codes (RFID) is used in place of the barcode scanner. In still other embodiments the identifying code is simply an alphanumeric password entered into a GUI on the transceiver by the medical professional. In all cases, the identifying code prompts the transceiver to render a GUI that is appropriate for the medical professional, but not necessarily for the patient. Such a GUI may include, for example, time-domain waveforms, vital sign information, and parameters relating to alarms/alerts. The GUI for the patient is typically much simpler, and includes information such as the time of day and a 'nurse call' button. To support this feature, the wrist-worn transceiver typically includes a speaker and system for communicating over the hospital's wireless network using standard voice over IP (VOIP) protocols. The speaker can also play pre-recorded messages that may be germane to the patient.

[0022] The GUI displayed by the wrist-worn transceiver may depend on the orientation of the transceiver. This can be determined, for example, by signals generated by an internal accelerometer. For example, when the transceiver is oriented to face a medical professional, the accelerometer can generate representative signals that can be processed by an internal CPU, which in response will render a GUI suitable for the medical professional. Alternatively, the CPU will render a GUI suitable for the patient when signals from the accelerometer indicate that the transceiver is oriented towards the patient.

[0023] The wrist-worn transceiver can communicate with a remote device through a wireless connection that operates on the hospital's wireless network, or alternatively through a peer-to-peer connection. In another aspect of the invention, for example, the remote device is configured to simultaneously display vital signs for each patient in a

group when a signal strength corresponding to each wrist-worn transceiver in the group is below a pre-determined threshold value. When the signal strength from the wireless system worn by a patient exceeds the pre-determine threshold, the remote monitor displays information for that particular patient. Such a situation would occur, for example, if a tablet computer normally disposed at a central nursing station was brought into the patient's room. Typically the pre-determined threshold value is between about -100 and -80 dB, and the wireless system used by each wrist-worn transceiver operates on an industry-standard communications protocol, preferably selected from 802.11, 802.15.4, and cellular wireless protocols. In embodiments, the remote device is a device comprising a microprocessor, a display, and a compatible communications transceiver. Examples include a computing device selected from the group consisting of a desktop computer, a portable computer, a tablet computer, a cellular telephone, and a personal digital assistant. This list is not meant to be limiting.

[0024] In yet another aspect, the invention provides a body-worn monitor featuring a 'hot swappable' battery. Here, the transceiver operates an algorithm that performs the following steps: (b) display on a GUI that the battery needs to be replaced; (c) detect when a secondary device is plugged into one of the serial ports, the secondary device indicating that the battery is about to be replaced; (d) store settings corresponding to the wireless system (e.g. IP and/or MAC addresses, passwords, encryption keys) and the patient's vital signs in the non-volatile memory; and (e) indicate on the GUI that the battery can be replaced. Once this is done, the depleted battery is replaced with a new one, and a button on the GUI is pressed to resume a wireless connection to the hospital's network. Continuous monitoring of the patient resumes once this is complete. Typically the secondary device plugs into a serial port on the transceiver, and sends a serial packet over the CAN bus indicating the battery is ready to be swapped.

[0047] Fig. 14 shows a three-dimensional view of the wrist-worn transceiver of Fig. 5C interfacing with a tablet computer and personal digital assistant (PDA) through, respectively, network and peer-to-peer wireless communication protocols;

[0048] Figs. 15A and 15B show, respectively, patient and map views used in the GUI rendered on the remote tablet computer of Fig. 14; and

[0049] Fig. 16 is a schematic drawing showing a sequence of pressure-dependent and pressure-free measurements made according to the Composite Technique using the body-worn monitor of Figs. 4A and 4B.

DETAILED DESCRIPTION OF THE INVENTION

[0050] **System Overview**

[0051] Fig. 1 shows a schematic drawing of a body-worn monitor 10 according to the invention featuring a wrist-worn transceiver 72 that continuously determines vital signs (e.g. blood pressure, SpO2, heart rate, respiratory rate, and temperature) and motion-related properties (e.g. posture, arm height, activity level, and degree of motion) for an ambulatory patient in a hospital. The monitor 10 is small, lightweight, and comfortably worn on the patient's body during their stay in the hospital; its form factor is described in detail below. A medical professional can apply the monitor, for example, to a recently admitted patient waiting in the ED, and the same monitor can provide continuous monitoring during their stay in the hospital. For example, the patient can wear the monitor in their hospital room, as they receive specific procedures or tests, during transport to other rooms, and even during surgery. The monitor 10 provides continuous monitoring, and features a software framework that determines alarms/alerts if the patient begins to decompensate. The framework processes both the patient's motion and their vital sign information with algorithms that reduce the occurrence of false alarms.

called a photoplethysmograph (PPG). Time-dependent features of the PPG indicate both pulse rate and a volumetric absorbance change in an underlying artery caused by the propagating pressure pulse.

[0005] Typical PTT measurements determine the time separating a maximum point on the QRS complex (indicating the peak of ventricular depolarization) and a foot of the PPG waveform (indicating the beginning the pressure pulse). PTT depends primarily on arterial compliance, the propagation distance of the pressure pulse (which is closely approximated by the patient's arm length), and blood pressure. To account for patient-dependent properties, such as arterial compliance, PTT-based measurements of blood pressure are typically 'calibrated' using a conventional blood pressure cuff and oscillometry. Typically during the calibration process the blood pressure cuff is applied to the patient, used to make one or more blood pressure measurements, and then left for future measurements. Going forward, the calibration measurements are used, along with a change in PTT, to continuously measure the patient's blood pressure (defined herein as 'cNIBP'). PTT typically relates inversely to blood pressure, i.e., a decrease in PTT indicates an increase in blood pressure.

[0006] A number of issued U.S. Patents describe the relationship between PTT and blood pressure. For example, U.S. Patents 5,316,008; 5,857,975; 5,865,755; and 5,649,543 each describe an apparatus that includes conventional sensors that measure an ECG and PPG, which are then processed to determine PTT. U.S. Patent 5,964,701 describes a finger-ring sensor that includes an optical system for detecting a PPG, and an accelerometer for detecting motion.

SUMMARY OF THE INVENTION

[0006a] The invention is defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

[0007] To improve the safety of hospitalized patients, particularly those in lower-acuity areas, it is desirable to have a body-worn monitor that continuously measures a

plurality of vital signs from a patient, and wirelessly transmits these directly to a nurse or to a central nursing station. Preferably the monitor operates algorithms featuring: 1) a low percentage of false positive alarms/alerts; and 2) a high percentage of true positive alarms/alerts. The term 'alarm/alert', as used herein, refers to an audio and/or visual alarm generated directly by a monitor worn on the patient's body, or alternatively a remote monitor (e.g., a central nursing station). To accomplish this, the exemplary techniques disclosed herewith provides a body-worn monitor that measures a patient's vital signs (e.g. blood pressure, SpO2, heart rate, respiratory rate, and temperature) while simultaneously characterizing their activity state (e.g. resting, walking, convulsing, falling) and posture (upright, supine). The body-worn monitor processes this information to minimize corruption of the vital signs and associated alarms/alerts by motion-related artifacts.

[0008] The body-worn monitor can include a software framework that generates alarms/alerts based on threshold values that are either preset or determined in real time. The framework additionally includes a series of 'heuristic' rules that take the patient's activity state and motion into account, and process the vital signs accordingly. These rules, for example, indicate that a walking patient is likely breathing and has a regular heart rate, even if their motion-corrupted vital signs suggest otherwise.

[0009] The body-worn monitor features a series of sensors that attach to the patient to measure time-dependent PPG, ECG, accelerometer-based motion (ACC), oscillometric (OSC), respiratory rate (RR), and impedance pneumography (IP) waveforms. A microprocessor (CPU) within the monitor continuously processes these waveforms to determine the patient's vital signs, degree of motion, posture and activity level. Sensors that measure these signals typically send digitized information to a wrist-worn transceiver through a serial interface, or bus, operating on a controlled area network (CAN) protocol. The CAN bus is typically used in the automotive industry, which allows different

electronic systems to effectively and robustly communicate with each other with a small number of dropped packets, even in the presence of electrically noisy environments. This is particularly advantageous for ambulatory patients that may generate signals with large amounts of motion-induced noise.

[0010] Blood pressure, a vital sign that is particularly useful for characterizing a patient's condition, is typically calculated from a PTT value determined from the PPG and ECG waveforms. Once determined, blood pressure and other vital signs can be further processed, typically with a server within a hospital, to alert a medical professional if the patient begins to decompensate.

[0011] In other embodiments, PTT can be calculated from time-dependent waveforms other than the ECG and PPG, and then processed to determine blood pressure. In general, PTT can be calculated by measuring a temporal separation between features in two or more time-dependent waveforms measured from the human body. For example, PTT can be calculated from two separate PPGs measured by different optical sensors disposed on the patient's fingers, wrist, arm, chest, or virtually any other location where an optical signal can be measured using a transmission or reflection-mode optical configuration. In other embodiments, PTT can be calculated using at least one time-dependent waveform measured with an acoustic sensor, typically disposed on the patient's chest. Or it can be calculated using at least one time-dependent waveform measured using a pressure sensor, typically disposed on the patient's bicep, wrist, or finger. The pressure sensor can include, for example, a pressure transducer, piezoelectric sensor, actuator, polymer material, or inflatable cuff.

[0012] In one exemplary technique, there is provided a body-worn monitor featuring a processing system that receives a digital data stream from an ECG system. A cable houses the ECG system at one terminal end, and plugs into the processing system, which

waveform and a digitized version of the analog waveform; (f) determining a calibration from the first digital waveform, the second digital waveform, and a digitized version of the analog waveform; and (g) determining a blood pressure value from the calibration and a pulse transit time.

[0019] Typically the optical signal is generated with an optical sensor configured to be worn around the patient's thumb. PTT is typically calculated from a time difference separating a QRS complex in the ECG waveform and a foot of a PPG waveform. In other embodiments the same optical sensor used to measure the optical waveform features a first LED operating in the red spectral range, and a second LED operating in the infrared spectral range. Optical waveforms measured with these LEDs can additionally be processed to determine SpO2, as is described in detail below.

[0020] The pressure signal is typically generated with a cuff-based pneumatic system wrapped around the patient's arm, and is typically measured during an inflation-based oscillometry measurement. Here, the processing component in the wrist-worn transceiver is further configured to calculate a calibration from a group of pulse transit times, wherein each pulse transit time in the group is measured when a different pressure is applied to the patient's arm. These data are then processed with a model that estimates an 'effective' blood pressure in the patient's arm during the inflation-based measurement, and uses this to estimate a relationship between PTT and blood pressure for the patient. This relationship represents a calibration that is then used with follow-on PTT measurements to measure the patient's cNIBP.

[0021] In another exemplary technique, there is provided a body-worn vital sign monitor featuring a processing component that includes a system for detecting an identifying code from a medical professional, and in response rendering a specific graphical user interface (GUI) on the wrist-worn transceiver. Preferably the system for detecting an identifying

code is a barcode printed on, e.g., the badge of the medical professional. Alternatively, a system based on radio-frequency identifying codes (RFID) is used in place of the barcode scanner. In still other embodiments the identifying code is simply an alphanumeric password entered into a GUI on the transceiver by the medical professional. In all cases, the identifying code prompts the transceiver to render a GUI that is appropriate for the medical professional, but not necessarily for the patient. Such a GUI may include, for example, time-domain waveforms, vital sign information, and parameters relating to alarms/alerts. The GUI for the patient is typically much simpler, and includes information such as the time of day and a 'nurse call' button. To support this feature, the wrist-worn transceiver typically includes a speaker and system for communicating over the hospital's wireless network using standard voice over IP (VOIP) protocols. The speaker can also play pre-recorded messages that may be germane to the patient.

[0022] The GUI displayed by the wrist-worn transceiver may depend on the orientation of the transceiver. This can be determined, for example, by signals generated by an internal accelerometer. For example, when the transceiver is oriented to face a medical professional, the accelerometer can generate representative signals that can be processed by an internal CPU, which in response will render a GUI suitable for the medical professional. Alternatively, the CPU will render a GUI suitable for the patient when signals from the accelerometer indicate that the transceiver is oriented towards the patient.

[0023] The wrist-worn transceiver can communicate with a remote device through a wireless connection that operates on the hospital's wireless network, or alternatively through a peer-to-peer connection. In another exemplary technique, for example, the remote device is configured to simultaneously display vital signs for each patient in a

group when a signal strength corresponding to each wrist-worn transceiver in the group is below a pre-determined threshold value. When the signal strength from the wireless system worn by a patient exceeds the pre-determine threshold, the remote monitor displays information for that particular patient. Such a situation would occur, for example, if a tablet computer normally disposed at a central nursing station was brought into the patient's room. Typically the pre-determined threshold value is between about -100 and -80 dB, and the wireless system used by each wrist-worn transceiver operates on an industry-standard communications protocol, preferably selected from 802.11, 802.15.4, and cellular wireless protocols. In embodiments, the remote device is a device comprising a microprocessor, a display, and a compatible communications transceiver. Examples include a computing device selected from the group consisting of a desktop computer, a portable computer, a tablet computer, a cellular telephone, and a personal digital assistant. This list is not meant to be limiting.

[0024] In yet another exemplary technique, there is provided a body-worn monitor featuring a 'hot swappable' battery. Here, the transceiver operates an algorithm that performs the following steps: (b) display on a GUI that the battery needs to be replaced; (c) detect when a secondary device is plugged into one of the serial ports, the secondary device indicating that the battery is about to be replaced; (d) store settings corresponding to the wireless system (e.g. IP and/or MAC addresses, passwords, encryption keys) and the patient's vital signs in the non-volatile memory; and (e) indicate on the GUI that the battery can be replaced. Once this is done, the depleted battery is replaced with a new one, and a button on the GUI is pressed to resume a wireless connection to the hospital's network. Continuous monitoring of the patient resumes once this is complete. Typically the secondary device plugs into a serial port on the transceiver, and sends a serial packet over the CAN bus indicating the battery is ready to be swapped.

[0047] Fig. 14 shows a three-dimensional view of the wrist-worn transceiver of Fig. 5C interfacing with a tablet computer and personal digital assistant (PDA) through, respectively, network and peer-to-peer wireless communication protocols;

[0048] Figs. 15A and 15B show, respectively, patient and map views used in the GUI rendered on the remote tablet computer of Fig. 14; and

[0049] Fig. 16 is a schematic drawing showing a sequence of pressure-dependent and pressure-free measurements made according to the Composite Technique using the body-worn monitor of Figs. 4A and 4B.

DETAILED DESCRIPTION OF THE INVENTION

[0050] **System Overview**

[0051] Fig. 1 shows a schematic drawing of a body-worn monitor 10 featuring a wrist-worn transceiver 72 that continuously determines vital signs (e.g. blood pressure, SpO2, heart rate, respiratory rate, and temperature) and motion-related properties (e.g. posture, arm height, activity level, and degree of motion) for an ambulatory patient in a hospital. The monitor 10 is small, lightweight, and comfortably worn on the patient's body during their stay in the hospital; its form factor is described in detail below. A medical professional can apply the monitor, for example, to a recently admitted patient waiting in the ED, and the same monitor can provide continuous monitoring during their stay in the hospital. For example, the patient can wear the monitor in their hospital room, as they receive specific procedures or tests, during transport to other rooms, and even during surgery. The monitor 10 provides continuous monitoring, and features a software framework that determines alarms/alerts if the patient begins to decompensate. The framework processes both the patient's motion and their vital sign information with algorithms that reduce the occurrence of false alarms.

What is claimed is:

1. A system for monitoring a patient, comprising:

a processing system configured to be worn on a patient's body and comprising a processor in electrical communication with a first connector configured to receive a digital data stream from an ECG system; and,

a cable comprising the ECG system and a second connector configured to removably connect to the first connector, the ECG system comprising: i) a connecting portion configured to connect to a plurality of electrodes configured to be worn on the patient; ii) a differential amplifier configured to receive electrical signals from each of the plurality of electrodes and process them to generate an analog ECG waveform; iii) an analog-to-digital converter configured to convert the analog ECG waveform into a digital ECG waveform; and iv) a transceiver component configured to transmit a digital data stream representing the digital ECG waveform or information calculated therefrom through the cable and to the processing system.

2. A cable comprising an ECG system configured to be worn on a first portion of a patient's body and to transit ECG information to a processing system worn on a second portion of the patient's body, the ECG system comprising: i) a differential amplifier configured to receive electrical signals from each of a plurality of electrodes connected to the patient and process them to generate an analog ECG waveform; ii) an analog-to-digital converter configured to convert the analog ECG waveform into a digital ECG waveform; and iii) and a transceiver component configured to transmit ECG information representing the digital ECG waveform or information calculated therefrom through the cable and to the processing system.

3. The system of claim 1, wherein the ECG system is comprised by a terminal end of the ECG cable.

4. The system of claim 3, wherein the cable comprises a housing at the terminal end that comprises at least a portion of the ECG system.

5. The system of claim 4, wherein the housing further comprises a motion-detecting sensor.

6. The system of claim 5, wherein the motion-detecting sensor is an accelerometer.

7. The system of claim 6, wherein the housing further comprises a temperature sensor.

8. The system of claim 7, wherein the temperature sensor is a thermocouple.

9. The system of claim 5, wherein the motion-detecting sensor is further configured to generate a digital motion waveform.

10. The system of claim 9, wherein the cable comprises at least one conductor configured to transmit both a first digital data stream representing the digital ECG waveform or information calculated therefrom, and a second digital data stream representing the digital motion waveform or information calculated therefrom.

11. The system of claim 10, wherein the first digital data stream comprises a first header portion and a first data portion, the first header portion indicating that the first data portion comprises ECG information.

12. The system of claim 11, wherein the first data portion comprises information indicating one of an ECG waveform, heart rate, an error code, and a physiological state corresponding to the patient.

13. The system of claim 10, wherein the second digital data stream comprises a second header portion and a second data portion, the second header portion indicating that the second data portion comprises motion information.

14. The system of claim 13, wherein the second data portion comprises information indicating one of an ACC waveform, degree of motion, posture, and an activity level.

15. The system of claim 1, wherein the transceiver component is a serial transceiver.

16. The system of claim 15, wherein the serial transceiver is a CAN transceiver configured to transmit a digital data stream according to a CAN protocol.

17. A system for monitoring a patient, comprising:

a processing system configured to be worn on a patient's body comprising at least three serial ports and a processor in electrical communication with each serial port, each serial port configured to receive a digital data stream from a unique sensor worn on the patient's body;

an ECG system comprising: i) a connecting portion configured to connect to a plurality of electrodes configured to be worn on the patient; ii) a differential amplifier configured to receive electrical signals from each of the plurality of electrodes and process them to generate an analog ECG waveform; iii) an analog-to-digital converter configured to convert the analog ECG waveform into a digital ECG waveform; iv) and a transceiver component configured to transmit a digital ECG data stream comprising the

digital ECG waveform or information calculated therefrom through a first serial port and to the processing system;

an oscillometry system comprising: i) a cuff configured to be worn on the patient and apply pressure to a portion of the patient; ii) a pneumatic system configured to inflate the cuff and detect pressure therein representing an analog oscillometric waveform; iii) an analog-to-digital converter configured to convert the analog oscillometric waveform into a digital oscillometric waveform; iv) a transceiver component configured to transmit a digital oscillometric data stream comprising the digital oscillometric waveform or values calculated therefrom through a second serial port and to the processing system; and

a third system configured to generate a third digital data stream and transmit the third digital data stream or values calculated therefrom through a third serial port to the processing system.

18. A system for monitoring a patient, comprising:

a processing system configured to be worn on a patient's body comprising multiple serial ports, each configured to receive a digital data stream from a sensor worn on the patient's body, and a processor in electrical communication with each serial port;

an ECG system configured to generate and transmit a digital ECG data stream comprising a digital ECG waveform or values calculated therefrom through a first serial port and to the processing system;

an oscillometry system configured to generate and transmit a digital oscillometric data stream comprising a digital oscillometric waveform or values calculated therefrom through a second serial port and to the processing system; and

a third system configured to generate and transmit a third digital data stream or values calculated therefrom through a third serial port to the processing system.

19. The system of claim 17, wherein the ECG system is configured transmit a digital ECG data stream comprising a header portion and a data portion, the header portion indicating that the data portion comprises ECG information.

20. The system of claim 19, wherein the data portion comprises information indicating one of an ECG waveform, heart rate, error code, and a physiological state corresponding to the patient.

21. The system of claim 17, wherein the oscillometry system is configured transmit a digital oscillometry data stream comprising a header portion and a data portion, the header portion indicating that the data portion comprises oscillometry information.

22. The system of claim 21, wherein the data portion comprises information indicating one of a pressure waveform, blood pressure, heart rate, error code, and a physiological state corresponding to the patient.

23. The system of claim 17, wherein the third system is configured transmit a digital data stream comprising a header portion and a data portion, the header portion indicating the system that generates the biometric signal.

24. The system of claim 23, wherein the third system is configured to deliver a compound to the patient.

25. The system of claim 24, wherein the third system is selected from the group consisting of an infusion pump, insulin pump, hemodialysis machine, and a mechanical ventilation system.

26. The system of claim 25, wherein the data portion comprises information indicating one of a type of compound delivered to the patient, a dosage of the compound, and a rate of delivery of the compound.

27. The system of claim 23, wherein the third system is a sensor configured to measure a signal from the patient.

28. The system of claim 27, wherein the sensor is selected from the group consisting of a pulse oximeter, EEG monitor, temperature sensor, respiratory rate sensor, motion sensor, camera, impedance plethysmography sensor, optical spectrometer, end-tidal CO2 monitor, and skin-conductance sensor.

29. The system of claim 28, wherein the data portion comprises information indicating one of PPG waveform, heart rate, pulse rate, SpO2 value, EEG waveform, temperature, respiratory rate, degree of motion, posture, activity level, arm height, an image, optical property of the patient, and electrical property of the patient.

30. The system of claim 17, wherein both the ECG system and the oscillometry system comprise a separate microprocessor, both of which are in communication with the processor comprised by the processing system.

31. The system of claim 30, wherein the processor comprised by the processing system is configured to send a packet to the microprocessor comprised by the ECG system to synchronize the processor and microprocessor.

32. The system of claim 31, wherein the microprocessor comprised by the ECG system is configured to adjust a timing parameter in response to the packet.

33. The system of claim 30, wherein the processor comprised by the processing system is configured to send a packet to the microprocessor comprised by the oscillometry system to synchronize the processor and microprocessor.

34. The system of claim 33, wherein the microprocessor comprised by the oscillometry system is configured to adjust a timing parameter in response to the packet.

35. The system of claim 17, wherein each of the processing system, ECG system, and oscillometry system comprise a serial transceiver.

36. The system of claim 35, wherein the serial transceiver comprised by each of the processing system, ECG system, and oscillometry system is a CAN transceiver.

37. A system for measuring a blood pressure value from a patient, comprising:

(a) a first sensor configured to generate a first time-dependent waveform indicative of one or more contractile properties of the patient's heart;

(b) a second sensor configured to generate a second time-dependent waveform indicative of one or more contractile properties of the patient's heart;

(c) a third sensor configured to generate a third time-dependent waveform indicative of pressure applied to a patient's arm; and

(d) a processing component configured to be worn on the patient's body and comprising a microprocessor and a serial transceiver, the processing component configured to: (i) communicate with a microprocessor and serial transceiver comprised by the first sensor to receive a digitized version of the first time-dependent waveform; (ii) communicate with a microprocessor and serial transceiver comprised by the third sensor to receive a digitized version of the third time-dependent waveform; (iii) calculate a pulse transit time calculated using a time difference between time-dependent features in digitized versions of the first and second time-dependent waveforms; (iv) calculate a

calibration from at least one pulse transit time and a pressure value determined from a digitized version of the third time-dependent waveform; and (v) calculate the blood pressure value from the pulse transit time and the calibration.

38. The system of claim 37, wherein the first sensor is an ECG sensor.

39. The system of claim 38, wherein the first time-dependent waveform is an ECG waveform.

40. The system of claim 38, wherein the second sensor is an optical sensor.

41. The system of claim 40, wherein the second time-dependent waveform is a PPG waveform.

42. The system of claim 37, wherein the third sensor is an inflatable cuff connected to a pneumatic system.

43. The system of claim 42, wherein the processing component is further configured to calculate a calibration from a blood pressure value determined from the third time-dependent waveform.

44. The system of claim 43, wherein the processing component is further configured to calculate a calibration from a group of pulse transit times, wherein each pulse transit time in the group is measured when a different pressure is applied to the patient's arm.

45. The system of claim 44, wherein the third time-dependent waveform is indicative of a pressure measured while the cuff is inflating.

46. The system of claim 45, wherein the processing component is further configured to calculate a relationship between pulse transit time and blood pressure to determine the calibration.

47. The system of claim 37, wherein the processing component is configured to connect to the pneumatic system with a cable configured to transmit serial data.

48. The system of claim 37, wherein the processing component is configured to be worn on the patient's wrist.

What is claimed is:

1. A system for monitoring a patient, comprising:

a processing system configured to be worn on a patient's body comprising at least three serial ports and a first processor in electrical communication with each serial port, each serial port configured to receive a digital data stream from a unique sensor worn on the patient's body;

an ECG system comprising: i) a connecting portion configured to connect to a plurality of electrodes configured to be worn on the patient; ii) a differential amplifier configured to receive electrical signals from each of the plurality of electrodes and process them to generate an analog ECG waveform; iii) an analog-to-digital converter configured to convert the analog ECG waveform into a digital ECG waveform; iv) a second processor; and (v) a transceiver component configured to operably connect the first processor and the second processor, to transmit a digital ECG data stream comprising the digital ECG waveform or information calculated therefrom through a first serial port and to the processing system, and to receive timing data from the processing system to synchronize timing between the second processor and the processing system;

an oscillometry system comprising: i) a cuff configured to be worn on the patient and apply pressure to a portion of the patient; ii) a pneumatic system configured to inflate the cuff and detect pressure therein representing an analog oscillometric waveform; iii) an analog-to-digital converter configured to convert the analog oscillometric waveform into a digital oscillometric waveform; iv) a third processor; and (v) a transceiver component configured to operably connect the first processor and the third processor to transmit a digital oscillometric data stream comprising the digital oscillometric waveform or values calculated therefrom through a second serial port and to the processing system, and to receive timing data from the

processing system to synchronize timing between the third processor and the processing system; and

a third system configured to generate a third digital data stream and transmit the third digital data stream or values calculated therefrom through a third serial port to the processing system.

2. The system of claim 1, wherein the ECG system is configured transmit a digital ECG data stream comprising a header portion and a data portion, the header portion indicating that the data portion comprises ECG information.

3. The system of claim 2, wherein the data portion comprises information indicating one of an ECG waveform, heart rate, error code, and a physiological state corresponding to the patient.

4. The system of claim 1, wherein the oscillometry system is configured transmit a digital oscillometry data stream comprising a header portion and a data portion, the header portion indicating that the data portion comprises oscillometry information.

5. The system of claim 4, wherein the data portion comprises information indicating one of a pressure waveform, blood pressure, heart rate, error code, and a physiological state corresponding to the patient.

6. The system of claim 1, wherein the third system is configured transmit a digital data stream comprising a header portion and a data portion, the header portion indicating the system that generates the biometric signal.

7. The system of claim 6, wherein the third system is configured to deliver a therapeutic agent to the patient.

8. The system of claim 7, wherein the third system is selected from the group consisting of an infusion pump, insulin pump, hemodialysis machine, and a mechanical ventilation system.

9. The system of claim 8, wherein the data portion comprises information selected from the group consisting of a type of compound delivered to the patient, a dosage of a compound to be delivered to the patient, and a rate of delivery of a compound to be delivered to the patient.

10. The system of claim 6, wherein the third system is a sensor configured to measure a signal from the patient.

11. The system of claim 10, wherein the sensor is selected from the group consisting of a pulse oximeter, EEG monitor, temperature sensor, respiratory rate sensor, motion sensor, camera, impedance plethysmography sensor, optical spectrometer, end-tidal $C0_2$ monitor, and skin-conductance sensor.

12. The system of claim 11, wherein the data portion comprises information indicating one of PPG waveform, heart rate, pulse rate, $Sp0_2$ value, EEG waveform, temperature, respiratory rate, degree of motion, posture, activity level, arm height, an image, optical property of the patient, and electrical property of the patient.

13. The system of claim 1, wherein each of the processing system, ECG system, and oscillometry system comprise a serial transceiver.

14. The system of claim 13, wherein the serial transceiver comprised by each of the processing system, ECG system, and oscillometry system is a CAN transceiver.